TITLE OF THE INVENTION

ZOOM LENS AND IMAGE PICKUP APPARATUS

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to a zoom lens with a wide angle of view and a high magnification, suitable for an image pickup apparatus such as a digital still camera, a video camera, or a television camera, etc.

2. Description of Related Art

[0002] Conventionally, a zoom lens comprising, in order from the object side, a first lens unit with positive optical power, a second lens unit with negative optical power, having a magnification varying function, and at least one other lens unit has been known. In this zoom lens, the first lens unit is provided with a retro focus type optical arrangement including a first lens component having negative optical power and a second lens component having positive optical power, wherein the first lens component has, in order from the object side, one negative lens element whose concave surface is faced to the object side, and one or more lens elements. Such a zoom lens is disclosed in Japanese Patent Application Laid-Open No. H08(1996)-184758 (corresponding to US Patent No. 5831771).

[0003] In such a zoom lens, since the back side principal

point of the first lens unit is pushed out toward the image plane side, the effective diameter of the first lens unit can be reduced to be comparatively small. Therefore, this zoom lens is frequently used as a wide-angle and high-magnification zoom lens whose zooming ratio exceeds 10 times.

[0004] Herein, for the zoom lens, reduction in size and weight has been strongly demanded as well as achievement of both a wide angle of view and a high magnification.

[0005] However, in the conventional structure such as disclosed in Japanese Patent Application Laid-Open No. H08(1996)-184758 (corresponding to US Patent No. 5831771), when it is attempted to realize a smaller size while achieving a wider angle of view, it becomes necessary to increase the negative optical power of the first lens component and the positive optical power of the second lens component.

[0006] If the positive optical power of the second lens component increases, positive distortion increases at a zooming position (focal length) of $fw \times Z^{1/4}$ provided that the focal length at the wide-angle end is fw and the zooming ratio is Z.

[0007] Furthermore, in addition to the increase in the negative optical power of the first lens component, in a case where the positive distortion is corrected, on the assumption that the maximum height of the maximum image

height off-axis light ray at the wide-angle end in a condition where the object distance is infinity is defined as hw, and the same at a zooming position of fw × $Z^{1/4}$ is defined as hz, the radius of curvature of the first surface (surface of the object side) of the negative lens element in the first lens component, satisfying hw < hz, becomes smaller.

[0008] As a result, the light ray incident angle onto the first surface of the negative lens element in the first lens unit increases, and distortion components in chromatic aberration of magnification significantly increase although positive distortion is satisfactorily corrected.

[0009] In order to correct this, it is necessary to make Abbe's number of the negative lens element in the first lens unit larger, however, this results in insufficient correction of axial chromatic aberration at the telephoto end, and it becomes difficult to achieve a wider angle and a higher magnification while maintaining high optical performance, furthermore, a smaller size and a lighter weight.

SUMMARY OF THE INVENTION

[0010] An object of the invention is to provide a small-sized lightweight zoom lens with a wide angle of view and a high magnification, having high optical performance by

setting the lens structure and conditions properly.

[0011] In order to achieve the abovementioned object, according to one aspect of the invention, a zoom lens comprises, in order from the object side, a first lens unit having positive optical power, a second lens unit having negative optical power and has a magnification varying function, and at least one other lens unit. The first lens unit includes, in order from the object side, a first negative lens element whose object side surface is concave toward the object side, and a second negative lens element, and at least one positive lens element is closer to the image plane side than the second negative lens element. And the zoom lens satisfies the following condition:

$$-1.28 < fn / f1$$

where fn denotes the composite focal length of the first negative lens element and the second negative lens element, and f1 denotes the focal length of the first lens unit.

[0012] The characteristics of a zoom lens and an image pickup apparatus of the invention become clear by the following detailed description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Fig. 1 is a sectional view of a zoom lens of Embodiment 1 of the invention when it is at the wide-angle

end and focused to infinity.

[0014] Fig. 2 is a sectional view of a zoom lens of Embodiment 2 of the invention when it is at the wide-angle end and focused to infinity.

[0015] Fig. 3 is a sectional view of a zoom lens of Embodiment 3 when it is at the wide-angle end and focused to infinity.

[0016] Figs. 4 are aberration diagrams of Embodiment 1 when the lens is at the wide-angle end and focused to infinity.

[0017] Figs. 5 are aberration diagrams of Embodiment 1 when the lens is focused to infinity at a focal length of fw $\times$ $Z^{1/4}$.

[0018] Figs. 6 are aberration diagrams of Embodiment 1 when the lens is at the telephoto end and focused to infinity.

[0019] Figs. 7 are aberration diagrams of Embodiment 2 when the lens is at the wide-angle end and focused to infinity.

[0020] Figs. 8 are aberration diagrams of Embodiment 2 when the lens is focused to infinity at a focal length of fw $\times$ $Z^{1/4}$.

[0021] Figs. 9 are aberration diagrams of Embodiment 2 when the lens is at the telephoto end and focused to infinity.

[0022] Figs. 10 are aberration diagrams of Embodiment 3 when the lens is at the wide-angle end and focused to infinity.

[0023] Figs. 11 are aberration diagrams of Embodiment 3 when the lens is focused to infinity at a focal length of fw $\times Z^{1/4}$.

[0024] Figs. 12 are aberration diagrams of Embodiment 3 when the lens is at the telephoto end and focused to infinity.

[0025] Fig. 13 is an optical path diagram of Embodiment 1 when the lens is at the wide-angle end and focused to infinity.

[0026] Fig. 14 is an optical path diagram of Embodiment 1 when the lens is focused to infinity at a focal length of fw $\times Z^{1/4}$.

[0027] Fig. 15 is an optical path diagram of Embodiment 2 when the lens is at the wide-angle end and focused to infinity.

[0028] Fig. 16 is an optical path diagram of Embodiment 2 when the lens is focused to infinity at a focal length of fw $\times Z^{1/4}$.

[0029] Fig. 17 is an optical path diagram of Embodiment 3 when the lens is at the wide-angle end and focused to infinity.

[0030] Fig. 18 is an optical path diagram of Embodiment 3

when the lens is focused to infinity at a focal length of fw $\times Z^{1/4}$.

[0031] Fig. 19 is a schematic view of an image pickup apparatus using the zoom lens of each abovementioned Embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] Hereinafter, Embodiments of the present invention are described with reference to the accompanying drawings.

[0033] Fig. 1, Fig. 2, and Fig. 3 are sectional views of zoom lenses of respective Embodiments 1, 2, and 3 when they are at the wide-angle end and focused to infinity.

[0034] In Fig. 1, Fig. 2, and Fig. 3, in order from an object side (left side of the drawings), numerical reference 1 denotes a first lens unit which has a focusing function and has positive optical power. Numerical reference 2 denotes a second lens unit which has a magnification varying function by moving on the optical axis and has negative optical power. Numerical referee 3 denotes third lens unit which moves on the optical axis when varying the magnification and corrects image plane variation caused by magnification varying. Numerical reference 4 denotes a fourth lens unit which has a function forming an image on the image plane and has positive optical power.

[0035] Numerical reference 31 denotes an aperture stop.

Numerical reference 32 denotes an optical unit including a color separating optical system and an optical filter, etc., which are shown by glass blocks corresponding to them in the figures.

[0036] The first lens unit 1 comprises, in order from the object side, a first lens component 11 which has negative optical power and is fixed when focusing, and a second lens component 12 which has positive optical power and moves on the optical axis when focusing.

[0037] The first lens component 11 includes, in order from the object side, a first negative lens element in which a first surface at the extreme object side is concave toward the object side, a second negative lens element, and at least one positive lens element.

[0038] In this embodiment, an example of the first lens component 11 which comprises, in order from the object side, a first negative lens element 21 and a second lens element unit 22 including a second negative lens element 22a and a positive lens element 22b is shown.

[0039] Thus, by making the first lens component 11 to include, in order from the object side, the negative lens element, the negative lens element, and at least one positive lens element, the radius of curvature of the first surface of the first negative lens element 21 can be increased even when the negative optical power of the first

lens component 11 and the positive optical power of the second lens component 12 are increased for a wider field angle of view and reduction in size and in weight of the zoom lens. Therefore, it becomes possible to suppress distortion components in chromatic aberration of magnification while satisfactorily correcting positive distortion which becomes maximum at a zooming position of fw $\times$ $Z^{1/4}$ provided that the focal length at the wide-angle end is fw and the zooming ratio is Z.

[0040] Furthermore, in Embodiments 1 and 2, an example in which a positive lens element 23 is disposed closer to the image plane side than the positive lens element 22b is shown. By disposing this positive lens element 23, the height of refraction point of off-axis light ray at the wide-angle side can be lowered in addition to the abovementioned effects, so that the diameter of the front lens (the first lens component 11) can be reduced. Furthermore, in Embodiments 1, 2, and 3, a structure of, in order from the object side, negative, negative, and positive is employed, however, a structure of negative, negative, negative, and positive may be employed. With such a structure, the radius of curvature of the first surface of the first negative lens element 21 can be increased, and a glass material having a large Abbe's number can be used for the first negative lens element 21, so that suppression of distortion components in

chromatic aberration of magnification is possible.

[0041] Furthermore, it is desirable that the following conditional expression is satisfied.

$-1.28 < fn < f1$ ...(1)

Herein, fn denotes the composite focal length of the first negative lens element 21 and the second negative lens element 22a, and f1 denotes the focal length of the first lens unit 1. If the lower limit of Expression (1) is exceeded, it becomes difficult to simultaneously realize suppression of distortion components in chromatic aberration of magnification and a wider angle while correcting excellently positive distortion which increases at a zooming position of $fw \times Z^{1/4}$ in the conventional structure. At the same time, the action of moving the principal point of the first lens unit 1 toward the second lens unit side is reduced, so that it becomes difficult to reduce the size of the entire zoom lens.

[0042] Furthermore, by satisfying the following conditional expression, it becomes possible to correct distortion components in chromatic aberration of magnification and axial chromatic aberration at the telephoto end while satisfactorily correcting positive distortion.

$\nu1 - \nu2 > 8$ ...(2)

$\nu3 > 60$ ...(3)

[0043] Herein, $\nu 1$ and $\nu 2$ indicate Abbe's numbers of the first negative lens element 21 and the second negative lens element 22a, respectively. $\nu 3$ denotes Abbe's number of the positive lens element which is disposed closer to the image plane side than the second negative lens element 22a and the closest to the object side within the first lens unit excluding the first negative lens element 21 and the second negative lens element 22a.

[0044] Expressions (2) and (3) indicate a condition required for achieving correction of both distortion components in chromatic aberration of magnification and axial chromatic aberration at the telephoto end. If $\nu 1 - \nu 2$ and $\nu 3$ are equal to or lower than the lower limit of Expressions (2) and (3), respectively, distortion components in chromatic aberration of magnification cannot be satisfactorily corrected, resulting in lowering in image quality.

[0045] Furthermore, in a case where the first lens component 11 constituting part of the first lens unit 1 comprises, in order from the object side, the first negative lens element 21 whose first surface is concave toward the object side, the second negative lens element 22a, and the positive lens element 22b, it is desirable that the zoom lens satisfies the following conditional expressions:

$Z > 10$ ...(4)

fw / IS < 0.75 ...(5)

[0046] Herein, Z denotes a zooming ratio, fw denotes a focal length of the entire system at the wide-angle end, and IS denotes an image size.

[0047] Expression (4) means that the zoom lens is a high-magnification zoom lens having a zooming ratio exceeding 10 times. If the zooming ratio Z becomes lower than the lower limit of Expression (4), it becomes unnecessary to increase the positive optical power of the first lens unit 1 and the negative optical power of the second lens unit 2, and distortion components in chromatic aberration of magnification can be suppressed while positive distortion is properly corrected even in the conventional structure. Therefore, the arrangement of a negative lens element, a negative lens element, and a positive lens element in order from the object side in the first lens component 11 becomes unnecessary.

[0048] Expression (5) means that the field angle at the wide-angle end is 67 degrees or more. When fw/IS becomes greater than the upper limit of (5), it becomes unnecessary to increase the positive optical power of the first lens unit 1 and the negative optical power of the second lens unit 2, and the arrangement of a negative lens element, a negative lens element, and a positive lens element in order from the object side in the first lens component 11 becomes

unnecessary.

[0049] All zoom lenses of Embodiments 1, 2, and 3 are high-magnification and wide-angle zoom lenses satisfying Expressions (1), (2), (3), (4)and (5) as shown in Tables 1, 2, and 3 below, wherein the first lens component 11 comprises, in order from the object side, a negative lens element, a negative lens element, and a positive lens element.

[0050] Furthermore, in a case where the first lens component 11 constituting part of the first lens unit 1 includes, in order from the object side, the negative lens element 21 whose first surface is concave toward the object side, the second negative lens element 22a, and the positive lens element 22b, it is desirable that the following condition is satisfied:

$hw < hz$ ...(6)

[0051] Herein, hw and hz show the maximum heights of off-axis light rays at the maximum image height, which pass through the first surface of the first lens unit 1 (the first negative lens element 21) when the zoom lens is focused to infinity at the wide-angle end and at a focal length of $fw \times Z^{1/4}$, respectively.

[0052] In such a zoom lens, in most cases, a negative lens element whose concave surface is faced to the image plane side is used as the first negative lens element 21 of the

first lens unit 1. In the zoom lens satisfying Expression (5), in a case where positive distortion is corrected, correction by the first surface of the first negative lens element 21 in the first lens component 11 satisfying $hw < hz$ is most suitable. Therefore, distortion components in chromatic aberration of magnification easily occur. Therefore, in the zoom lens satisfying Expression (6), the first lens component 11 is composed of, in order from the object side, a negative lens element, a negative lens element, and a positive lens element.

[0053] Fig. 13 through Fig. 18 are optical path diagrams showing off-axis light rays at the maximum image height that pass through the first surface of the first lens unit 1 at the wide-angle end and at a focal length of $fw \times Z^{1/4}$ in Embodiment 1, Embodiment 2, and Embodiment 3.

[0054] As shown in these figures and Tables 1 through 3, in this embodiment, in the zoom lenses satisfying Expression (6), the first lens component 11 includes a negative lens element, a negative lens element, and a positive lens element.

[0055] As a more preferable embodiment, it is desirable that the second negative lens element 22a and the positive lens element 22b, which form the first lens component 11, are cemented together.

[0056] The positive lens element 22b has a function to

correct spherical aberration at the telephoto end, however, in a case where an air space exists between the second negative lens element 22a and the positive lens element 22b, the sensitivity of spherical aberration to the interval between the second negative lens element 22a and the positive lens element 22b increases, resulting in more production difficulty. Therefore, it is preferable that the second negative lens element 22a and the positive lens element 22b are cemented together to form the second lens element unit 22 as a cemented lens.

[0057] (Numerical examples)

Numerical data of the zoom lens of Embodiment 1 shown in Fig. 1 is shown in Table 1, numerical data of the zoom lens of Embodiment 2 shown in Fig. 2 is shown in Table 2, and numerical data of the zoom lens of Embodiment 3 shown in Fig. 3 is shown in Table 3.

[0058] In these tables, ri denotes the radius of curvature of the i-th surface in order from the object side, di denotes the interval between the i-th surface and (i+1)th surface, and ni and νi are the refractive index and Abbe's number of the glass material forming the i-th surface, respectively.

[0059] Furthermore, the surface attached with an "*" indicates that the surface is an aspherical surface. The shape of the aspherical surface satisfies the following

expression when the direction of the optical axis is defined as the x axis, the direction perpendicular to the optical axis is defined as the y axis, the light ray advance direction is defined as positive, R is defined as the paraxial radius of curvature, and k, B, C, D, E, F, A', B', C', D', and E' are defined as aspherical coefficients:

$$x = \{(y^2/R) \ / \ (1-(1+k)\cdot(y/R)^2)^{1/2}\} + By^4 + Cy^6 + Dy^8 + Ey^{10} + Fy^{12} + A'y^3 + B'y^5 + C'y^7 + D'y^9 + E'y^{11}$$

[0060]

<Table 1>

Zooming ratio: 21x

Field angle at the wide-angle end: 70.4 degrees

ν1-ν2=29.3   ν3=95.0   hw:5.13   hz:5.21

fn/f1=-1.07

r1=	-27.3632	d1=	0.2308	n1=	1.73234	ν1=	54.7
r2=	27.3632	d2=	0.7159				
r3=	71.3705	d3=	0.2308	n2=	1.81264	ν2=	25.4
r4=	12.9897	d4=	1.9149	n3=	1.43985	ν3=	95.0
r5=	-20.8550	d5=	0.0192				
r6=	22.4921	d6=	1.0621	n4=	1.62033	ν4=	63.3
r7=	-44.2413	d7=	0.8682				
r8=	13.6623	d8=	1.3612	n5=	1.49845	ν5=	81.5
r9=	-38.6827	d9=	0.0192				
r10=	8.5777	d10=	0.8358	n6=	1.73234	ν6=	54.7
r11=	20.4377	d11=	variable				
*r12=	17.4102	d12=	0.0897	n7=	1.88815	ν7=	40.8
r13=	1.8153	d13=	0.7775				
r14=	-16.8508	d14=	0.8569	n8=	1.81643	ν8=	22.8
r15=	-1.7598	d15=	0.0897	n9=	1.82017	ν9=	46.6
r16=	6.2738	d16=	0.0207				
r17=	3.0458	d17=	0.7632	n10=	1.53430	ν10=	48.8

r18=	-3.7054	d18=	0.0339				
r19=	-3.3339	d19=	0.0897	n11=	1.83945	ν11=	42.7
r20=	-33.1779	d20=	variable				
r21=	-3.6233	d21=	0.0897	n12=	1.74678	ν12=	49.3
r22=	5.8983	d22=	0.3590	n13=	1.85504	ν13=	23.8
r23=	-168.4231	d23=	variable				
r24=	0.0000	d24=	0.1667 (aperture stop)				
r25=	140.3963	d25=	0.5587	n14=	1.66152	ν14=	50.9
r26=	-4.4981	d26=	0.0192				
r27=	10.3658	d27=	0.3130	n15=	1.51825	ν15=	64.1
r28=	-3371.7949	d28=	0.0192				
r29=	11.9041	d29=	0.8686	n16=	1.51825	ν16=	64.1
r30=	-4.1625	d30=	0.2308	n17=	1.83932	ν17=	37.2
r31=	-26.2383	d31=	4.5128				
r32=	7.8669	d32=	0.8029	n18=	1.51825	ν18=	64.1
r33=	-6.7440	d33=	0.2219				
r34=	-12.6572	d34=	0.2308	n19=	1.83945	ν19=	42.7
r35=	4.1168	d35=	0.7369	n20=	1.51977	ν20=	52.4
r36=	-11.6979	d36=	0.5637				
r37=	7.9839	d37=	0.8684	n21=	1.48915	ν21=	70.2
r38=	-3.8229	d38=	0.2308	n22=	1.83932	ν22=	37.2
r39=	-45.5666	d39=	0.0192				
r40=	6.8645	d40=	0.5644	n23=	1.52033	ν23=	58.9
r41=	-9.4753	d41=	0.5769				
r42=	0.0000	d42=	3.8462	n24=	1.60718	ν24=	38.0
r43=	0.0000	d43=	2.0769	n25=	1.51825	ν25=	64.2
r44=	0.0000	d44=	0.9614				

Focal length /Variable interval	1.00	2.14	4.06	14.60	21.00
d11	0.09	3.06	4.71	6.58	6.85
d20	7.14	3.74	1.80	0.45	0.70
d23	0.62	1.06	1.34	0.82	0.22

Aspherical coefficient of twelfth surface

R	k	B	C	D	E	F
17.410	8.589	4.141×10^{-3}	-5.492×10^{-4}	1.667×10^{-4}	-1.047×10^{-4}	4.778×10^{-5}
	A'	B'	C'	D'	E'	
	-6.080×10^{-5}	-2.190×10^{-4}	-1.086×10^{-4}	2.765×10^{-4}	-1.157×10^{-4}	

[0061]

<Table 2>

Zooming ratio: 18x

Field angle at the wide-angle end: 72.5 degrees

ί1-ί2=24.6 ί3=95.0 hw:5.50 hz:5.52

fn/f1=-1.10

r1=	-28.9573	d1=	0.2400	n1=	1.79025	ί1=	50.0
r2=	30.0203	d2=	0.8515				
r3=	78.0457	d3=	0.2400	n2=	1.81264	ί2=	25.4
r4=	13.9770	d4=	2.0645	n3=	1.43985	ί3=	95.0
r5=	-20.9743	d5=	0.0200				
r6=	24.9264	d6=	1.1292	n4=	1.60520	ί4=	65.4
r7=	-39.7140	d7=	0.7266				
r8=	14.2826	d8=	1.4278	n5=	1.49845	ί5=	81.5
r9=	-36.6365	d9=	0.0200				
r10=	8.3007	d10=	0.8977	n6=	1.73234	ί6=	54.7
r11=	18.7300	d11=	variable				
*r12=	17.2263	d12=	0.0933	n7=	1.88815	ί7=	40.8
r13=	2.0230	d13=	0.7765				
r14=	-16.8024	d14=	0.8726	n8=	1.81643	ί8=	22.8
r15=	-1.8979	d15=	0.0933	n9=	1.82017	ί9=	46.6
r16=	5.0474	d16=	0.1466				
r17=	3.2941	d17=	0.7571	n10=	1.57047	ί10=	42.8
r18=	-4.0079	d18=	0.0787				
r19=	-3.1712	d19=	0.0933	n11=	1.88815	ί11=	40.8
r20=	-18.0496	d20=	variable				
r21=	-3.5834	d21=	0.0933	n12=	1.74678	ί12=	49.3
r22=	6.3668	d22=	0.3733	n13=	1.85504	ί13=	23.8
r23=	-97.8600	d23=	variable				
r24=	0.0000	d24=	0.1733 (aperture stop)				
r25=	168.4641	d25=	0.6109	n14=	1.66152	ί14=	50.9
r26=	-4.4111	d26=	0.0200				
r27=	11.1625	d27=	0.3447	n15=	1.51977	ί15=	52.4
r28=	-1200.0000	d28=	0.0200				
r29=	10.5857	d29=	0.7931	n16=	1.52458	ί16=	59.8
r30=	-3.9079	d30=	0.2400	n17=	1.83945	ί17=	42.7
r31=	-21.0878	d31=	3.3333				

r32=	10.2483	d32=	0.7729	n18=	1.51825	ı18=	64.1
r33=	-5.8053	d33=	0.1364				
r34=	-9.2298	d34=	0.2400	n19=	1.83945	ı19=	42.7
r35=	4.2865	d35=	1.1027	n20=	1.51825	ı20=	64.1
r36=	-7.7621	d36=	0.3999				
r37=	10.0271	d37=	0.8147	n21=	1.48915	ı21=	70.2
r38=	-3.8930	d38=	0.2400	n22=	1.83932	ı22=	37.2
r39=	-25.1689	d39=	0.0366				
r40=	7.0822	d40=	0.6865	n23=	1.51825	ı23=	64.1
r41=	-8.9491	d41=	0.6000				
r42=	0.0000	d42=	4.0000	n24=	1.60718	ı24=	38.0
r43=	0.0000	d43=	2.1600	n25=	1.51825	ı25=	64.2
r44=	0.0000	d44=	1.0136				

Focal length /Variable interval	1.00	2.06	4.06	14.70	18.00
d11	0.08	2.94	4.72	6.59	6.75
d20	7.16	3.89	1.82	0.47	0.61
d23	0.29	0.71	1.01	0.48	0.18

Aspherical coefficient of twelfth surface

R	k	B	C	D	E	F
17.226	8.589	3.651×10^{-3}	-6.001×10^{-4}	1.193×10^{-4}	-6.848×10^{-5}	2.671×10^{-5}
	A'	B'	C'	D'	E'	
	-3.332×10^{-4}	-1.912×10^{-4}	-9.353×10^{-5}	2.253×10^{-4}	-7.330×10^{-5}	

[0062]

<Table 3>

Zooming ratio: 20x

Field angle at the wide-angle end: 67.7 degrees

ν1-ν2=9.9 ν3=65.4 hw:4.78 hz:5.07

fn/f1=-1.23

r1= -30.1125	d1= 0.21951	n1= 1.75453	ν1= 35.3
r2= 28.3260	d2= 0.80928		
r3= 56.8148	d3= 0.21951	n2= 1.81264	ν2= 25.4
r4= 14.9249	d4= 1.69238	n3= 1.60520	ν3= 65.4
r5= -19.2336	d5= 0.91378		
r6= 14.8215	d6= 0.91117	n4= 1.49845	ν4= 81.5
r7= 599.6105	d7= 0.01829		
r8= 12.8169	d8= 0.77823	n5= 1.60520	ν5= 65.4
r9= 58.8537	d9= 0.01829		
r10= 8.4780	d10= 0.71456	n6= 1.73234	ν6= 54.7
r11= 19.3234	d11=variable		
*r12= 27.8681	d12= 0.08537	n7= 1.88815	ν7= 40.8
r13= 1.9627	d13= 0.72265		
r14= -15.0271	d14= 0.80385	n8= 1.81264	ν8= 25.4
r15= -1.8450	d15= 0.08537	n9= 1.75844	ν9= 52.3
r16= 3.7430	d16= 0.08325		
r17= 2.8552	d17= 0.6843	n10= 1.60718	ν10= 38.0
r18= -4.8336	d18= 0.1069		
r19= -3.0309	d19= 0.08537	n11= 1.83945	ν11= 42.7
r20= -16.4257	d20=variable		
r21= -3.4527	d21= 0.08537	n12= 1.74678	ν12= 49.3
r22= 5.7000	d22= 0.34146	n13= 1.85504	ν13= 23.8
r23= -321.3362	d23=variable		
r24= 0.0000	d24= 0.15854 (aperture stop)		
r25= 43.9054	d25= 0.53392	n14= 1.66152	ν14= 50.9
r26= -4.2550	d26= 0.01829		
r27= 11.3523	d27= 0.26799	n15= 1.51825	ν15= 64.1
r28= -454.6526	d28= 0.01829		
r29= 10.9151	d29= 0.73123	n16= 1.51825	ν16= 64.1
r30= -3.9122	d30= 0.21951	n17= 1.83932	ν17= 37.2
r31= -25.7207	d31= 4.29268		

r32=	6.1897	d32=	0.71707	n18=	1.51825	ν18=	64.1
r33=	-6.5219	d33=	0.2032				
r34=	-9.4702	d34=	0.21951	n19=	1.83945	ν19=	42.7
r35=	3.5244	d35=	0.76257	n20=	1.51977	ν20=	52.4
r36=	-10.7857	d36=	0.50836				
r37=	10.5784	d37=	0.84487	n21=	1.48915	ν21=	70.2
r38=	-3.7200	d38=	0.21951	n22=	1.83932	ν22=	37.2
r39=	-17.4607	d39=	0.02156				
r40=	6.3961	d40=	0.59703	n23=	1.52033	ν23=	58.9
r41=	-8.6239	d41=	0.54878				
r42=	0.0000	d42=	3.65854	n24=	1.60718	ν24=	38.0
r43=	0.0000	d43=	1.97561	n25=	1.51825	ν25=	64.2
r44=	0.0000	d44=	0.91424				

Focal length /Variable interval	1.00	2.11	4.06	13.33	20.00
d11	0.08	2.85	4.47	6.16	6.47
d20	6.74	3.57	1.69	0.43	0.73
d23	0.54	0.93	1.19	0.76	0.16

Aspherical coefficient of twelfth surface

R	k	B	C	D	E	F
27.868	8.589	3.889×10^{-3}	-6.685×10^{-4}	1.869×10^{-4}	-1.344×10^{-4}	6.539×10^{-5}
	A'	B'	C'	D'	E'	
	-3.026×10^{-5}	7.506×10^{-5}	-2.698×10^{-4}	4.075×10^{-4}	-1.610×10^{-4}	

[0063] Furthermore, in Embodiment 1, Embodiment 2 and Embodiment 3, aberration diagrams when the lenses are at the wide-angle end and focused to infinity, aberration diagrams when the lenses are focused to infinity at a focal length of $fw \times Z^{1/4}$, and aberration diagrams when the lenses are at the telephoto end and focused to infinity are shown in Figs. 4 through Figs. 12.

[0064] In all cases, although distortion components in chromatic aberration of magnification at the wide-angle end are small, positive distortion at a focal length of $fw \times Z^{1/4}$ and axial chromatic aberration at the telephoto end are satisfactorily corrected.

[0065] As described above, according to each embodiment, a zoom lens which is small in size and lightweight while having high optical performance, a wide field angle, and a high magnification is realized.

[0066] Fig. 19 shows a video camera (image pickup apparatus) using the zoom lens described in each embodiment as an image-taking optical system.

[0067] In Fig. 19, numerical reference 50 denotes the main body of the video camera, 51 denotes an image-taking optical system comprising the zoom lens described in each embodiment, and 52 denotes an image pickup element as a photoelectrically converting element such as a CCD or a CMOS sensor, etc., which receives and photoelectrically converts

an object image formed by the image-taking optical system 51.

[0068] A recording medium 53 is a semiconductor memory, a magnetic disk, or an optical disk, etc., which records image signals obtained through the image pickup element 52. A finder 54 is for observation of an object image displayed on an internal display panel (not shown) such as a liquid crystal panel, etc., in response to the image signals obtained through the image pickup element 52.

[0069] An external display panel 55 has a function equivalent to that of the finder 54, and is a liquid crystal panel, etc., which displays object images and various image-taking information. This external display panel 55 can be housed in and developed from the video camera main body 50, and the housed condition is shown in the figure.

[0070] By using the above-described zoom lens as an image-taking optical system, an image pickup apparatus which is small in size and lightweight while having high image pickup performance and enables image-taking with a wide field angle and a high magnification is realized.

[0071] The zoom lens described in each embodiment mentioned above can be used for various image pickup apparatuses including digital still cameras, television cameras, and film cameras as well as video cameras.

[0072] While preferred embodiments have been described, it is to be understood that modification and variation of the

present invention may be made without departing from the scope of the following claims.